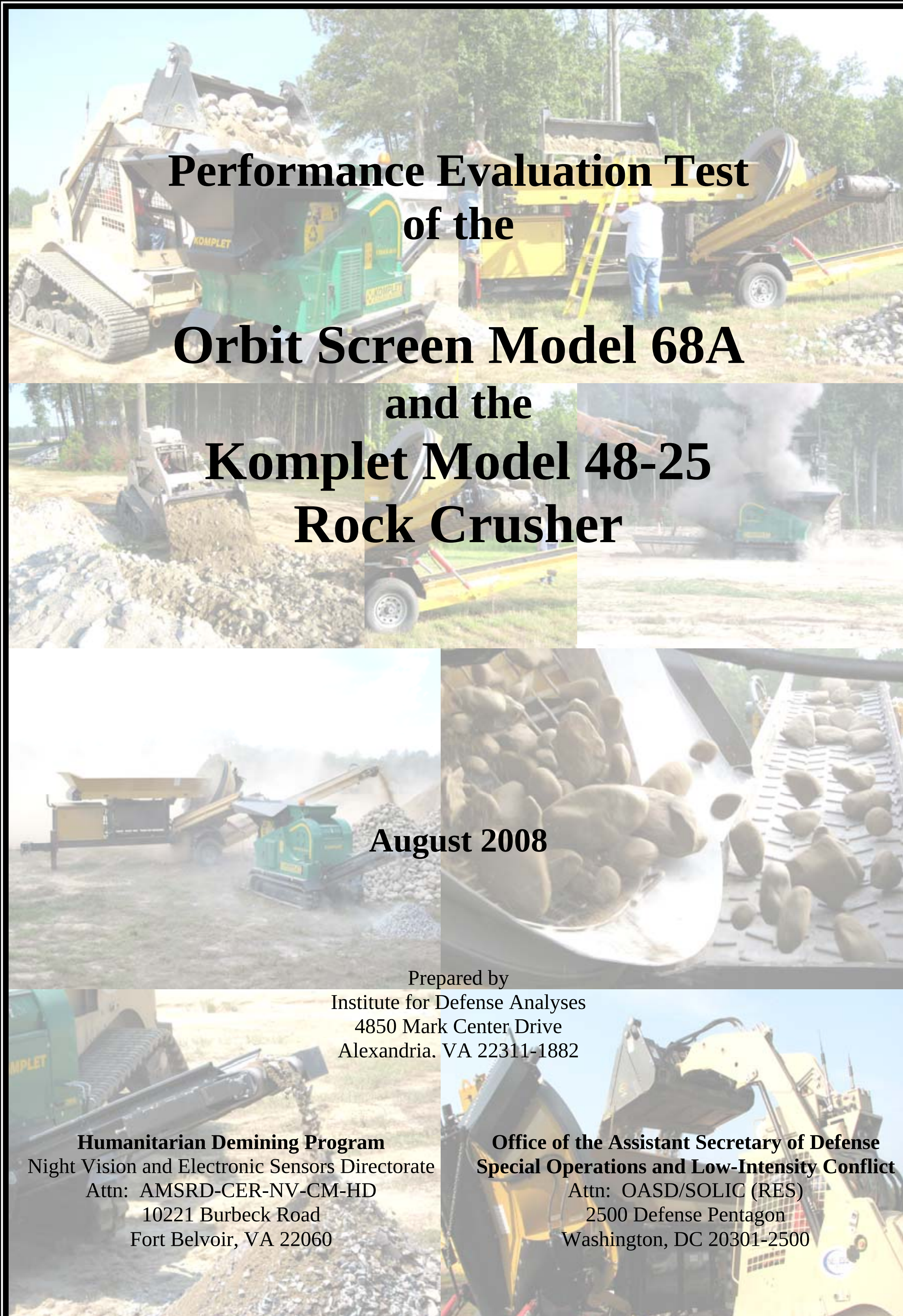

Performance Evaluation Test of the

Orbit Screen Model 68A

and the

Komplet Model 48-25 Rock Crusher

August 2008

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PREFACE

As the result of attending a U.S. Humanitarian Demining Requirements Workshop, the Demining Center of Ecuador requested the assistance of the U.S. Humanitarian Demining Research and Development Program in addressing the cleanup of minefields along the Rio Chira on the Ecuador-Peru border. The minefields, a result of the conflict between the two countries during the 1970s through the 1990s, are in the shoreline along the Rio Chira close to centers of population. In some cases, the minefields deny easy access to the river for use by the local populace. In all cases, the minefields are a continuous threat to the safety of the local inhabitants.

An on-site survey of the minefields defined the problems that had to be faced. The minefields were laid along a shoreline made up of river-run stones, gravel, and sand. Based on information available, it was determined that the main threat was from TAB-1 antipersonnel mines. The main problem to be solved was how to remove the mines in a safe manner from a soil/rock mixture that was predominantly rocks.

Two machines, an orbital sifter and a rock crusher, were each judged able to do the job. Under the direction of Chris Wanner, functioning as the project engineer and the test director, a performance evaluation test was conducted on an Orbit Screen, Inc., Model 68A orbital screen and on a Komplet Italia, s.r.l., Model 48-25 rock crusher. The test was conducted during August 2008 at a U.S. Army test site in central Virginia. Chris Wanner, as test director, received technical support from Sarah Heaton of Fibertek, Inc. and from Hal Bertrand and Jennifer Soult from the Institute for Defense Analyses (IDA). Equipment and logistic support was provided by John Snellings and Arthur Limerick, members of the test facility staff. This report was prepared by Hal Bertrand, Jennifer Soult, and Tom Milani of IDA.

Special mention is made here of the participation of two representatives from the Government of Ecuador, Ms. Viviana Anabela Meza Cevallos, from the Demining Center of Ecuador, and Lieutenant Jose Luis Aroca Pabon, a combat engineer from the Army of Ecuador. While their initial reason for attending was to act as observers of the test, they quickly became involved as part of the test team by assisting in the collection of test data. For their pleasant demeanor, quick smiles, and cheerful assistance, we thank you.

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FIGURES

TABLES

1 Purpose

At the request of the Demining Center of Ecuador, the U.S. Humanitarian Demining Research and Development Program at Ft. Belvoir, VA., undertook a performance evaluation of the Orbit Screen Model 68A and the Model 48-25 Rock Crusher, two pieces of equipment that could be used to remove antipersonnel land mines from riverbank minefields along the border of Ecuador and Peru. Although these devices could conceivably be used in tandem as a system, this evaluation focused on the performance potential of each unit to operate as a stand-alone system. A test was also conducted to see how long it would take the ASV SR-80, a small rubber-tracked loader, to process 90–100 m^3 of material, spread to an average depth of about 50 cm (representing a minefield), through the orbital screener. The Quick Combo Bucket was used with the ASV SR-80. Finally, a demonstration was conducted to determine if the orbital screener and rock crusher could be used in tandem as a system.

2 System Description

2.1 Orbit Screen, Inc., Model 68 Orbital Screener

The Orbit Screen Model 68 (Figure 1) is a stand-alone sifter that separates large material from soil or sand. Material to be sifted is first loaded into the sifter's hopper, located at the top of the machine, then conveyed into the orbital screen. As the dish-like screen rotates, the rock and soil are tumbled within the screen, allowing soil, sand, and small particles to fall through the mesh. These smaller particles are conveyed away by the belt at the rear of the machine, creating a mound of soil and small particles. Larger objects (i.e., those objects that did not fall through the screen) are tumbled out of the screen onto a separate conveyor belt, which moves these items to a pile at the side of the machine. Various size interchangeable screens are available to suit a job's requirements. Table 1 gives the specifications of the Orbit Screen Model 68.

Figure 1: Orbit Screen Model 68

Table 1: Orbit Screen Model 68 Specifications

Orbit Screen Model 68	Measurement Dimensions
Operating weight	3,518 kg / 7,740 lbs
Engine type	Yanmar water-cooled diesel 3TNV828
Net engine power	19.4 kW / 26 hp
Length	10.3 m / 33.8 ft
Width	2.3 m / 7.5 ft
Height	2.9 m / 9.5 ft
Axle weight	2,773 kg / 6,100 lbs
Hopper feeder capacity	1.38 m^3 / 1.8 yd^3
Hopper loading height	2.4 m / 7.7 ft
Screen diameter	1.8 m / 6 ft
Screen material discharge height	10 – 11 ft
Manufacturer's nominal rating	50 m^3 / hr

2.2 Komplet Italia, s.r.l., Model 48-25 Rock Crusher

The tracked Komplet Rock Crusher, Model 48-25 (Figure 2), is built by Komplet Italia, s.r.l., in both Italy and Slovenia. The tracked model is self-deployable over short distances, with a maximum speed of about that of a leisurely walk. While slow, this mobility is invaluable on a job site where frequent relocating of the machine is required. The distance between the crushing jaws is adjustable from 10 mm to over 50 mm. The machine is remotely controlled with a belt-portable radio control unit. Table 2 gives the specifications for the unit.

Figure 2: Komplet Rock Crusher

Table 2: Komplet Italia s.r.l. Model 48-25 Rock Crusher Specifications

Komplet Rock Crusher	Measurement Dimension
Weight	3,400 kg / 7,840 lbs
Engine, Isuzu 3-cylinder diesel	21 kW / 28.5 hp @2,000 rpm
Height	1.90 m / 6.23 ft
Width	1.45 m / 4.6 ft
Working length	3.50 m / 11.5 ft
Rated output (depending on material)	up to 15 m^3 / hr

2.3 ASV SR-80 Rubber-Tracked Skid-Steer Loader

The ASV SR-80 vehicle, in addition to being a loader, can operate a suite of area-preparation tools. The hydraulic track-laying drive system gives the operator the ability to maneuver in all types of terrain, as well as perform 180-degree turns within its own length. Table 3 lists the specifications for the ASV SR-80.

Figure 3: ASV SR-80 Rubber-Tracked Loader

Table 3: ASV SR-80 Specifications

ASV SR-80	Dimensions
Vehicle-only weight	3,980 kg / 8,780 lbs
Length, width, height	2.85 m × 1.83 m × 2.49 m
Ground clearance	0.381 m
Ground pressure	21.7 kPa / 3.15 psi
Track width	0.508 m / 20 in
Ground contact area	1.83 m^2 / 2,840 in^2
Engine type	Perkins 804C-33T diesel, TC
Gross power @ 2,600 RPM	60 kW / 80 hp
Torque, peak	253 N·m / 186 ft-lb
Auxiliary hydraulic system, high flow	113.6 Lpm / 30 gpm
Auxiliary hydraulic system, low flow	75.7 Lpm / 20 gpm
Max. hydraulic system pressure	20,678 kPa / 3,000 psi
Fuel capacity	68 L / 18 gal
Hydraulic fluid capacity	79 L / 21 gal

2.4 4-in-1 Quick Combo Bucket

The 4-in-1 bucket (the Quick Combo Bucket) built by Quick Attach Attachments, Inc., was used with the ASV SR-80 vehicle during this test to load the representative minefield soil into the orbit screener and the rock crusher. As shown in Figure 4, the 4-in-1 bucket can be used as a shovel or scoop to pick up and move debris, or it can be used as a plow/light grapple to push debris into berms for later disposal. Table 4 gives the specifications.

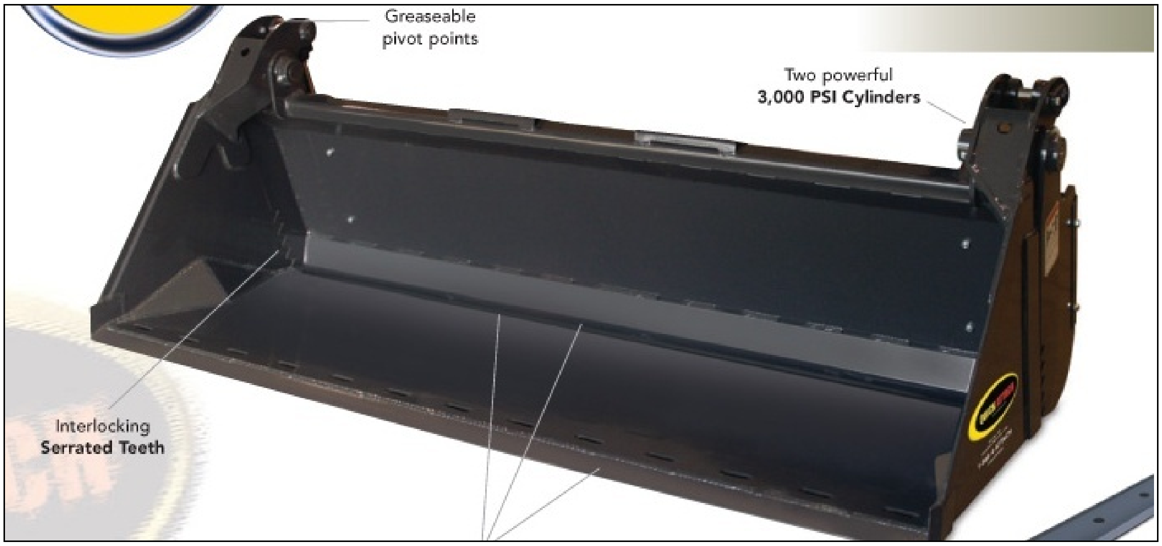

Figure 4: Quick Combo, 4-in-1 Bucket

Table 4: Quick Combo 4-in-1 Bucket Specs

Quick Combo Bucket	Metrics
Width	188 cm / 74 in
Weight	382 kg / 840 lb
Volume	0.32 m^3
Open-wide angle	75°

3 Test Material Description

3.1 Rock and Soil Mix

A mix of soils judged to be similar to the soil comprising the minefields in Ecuador was acquired for the test program. Table 5 gives the composition of the test soil. The total volume of various rock sizes and soils procured was about 116 m^3. Based on the principle that a glass of marbles and a glass of sand will total less than two glasses of material when mixed, the total material available for the test was estimated to be 110 m^3. The rocks in this sandy soil mixture ranged in size from tennis-ball sized to volleyball sized (see Figures 5 and 6).

Table 5: Test Soil Composition and Volumes Acquired

Test Soil Components	Volume Acquired
25.4–76 mm / 1–3 inch Riverjack	17.4 m^3 / 22.8 yd^3
76–127 mm / 3–5 inch Riverjack	34.8 m^3 / 45.5 yd^3
127–203 mm / 5–8 inch Riverjack	8.7 m^3 / 11.4 yd^3
Stone dust	17.4 m^3 / 22.8 yd^3
Sand	34.8 m^3 / 45.5 yd^3
Total	**116.7** m^3 / **148** yd^3

Figure 5: Rock/Soil Mix

Figure 6: Rock/Soil Mix

3.2 PVC Mock Antipersonnel Mines

Cylindrical PVC simulated antipersonnel mines (Figure 7) were used in the orbit screen and rock crusher tests. These simulated mines, intended to represent the predominant mine threat in the Ecuadorian minefields, the TAB-1, were constructed of black PVC sealed on both ends and filled with hardened plaster. The PVC stimulant mines are 2.75 in (70 mm) high and 2.38 in. (60 mm) in diameter.

Figure 7: PVC Mock Mine

3.3 Mechanical Reproduction Mine (MRM) Antipersonnel Simulants

Antipersonnel mine simulants produced by Amtech Aeronautical Limited of Alberta, Canada, were used to determine the possibility of triggering antipersonnel mines during loading and sifting operations of the orbital screener. These plastic mines, shown in Figures 8–11, are designed to simulate the necessary pressure and detonating mechanisms used to trigger the mines represented by the simulant types. A reader (Figure 12), similar in design to a metal detector, is used to determine whether or not the mine simulant was triggered.

Figure 8: MRM Simulant, Type 72 Antipersonnel Mine

Figure 9: MRM Simulant, PMN Antipersonnel Mine

Figure 10: MRM Simulant, PMA-1 Antipersonnel Mine

Figure 11: MRM Simulant, PMA-2 Antipersonnel Mine

Figure 12: MRM Reader

4 Orbit Screen Model 68 Testing

4.1 Processing Test

Three full bucket loads of the rock/soil mix were placed, one at a time, into the hopper of the Orbit Screen Model 68 sifter and timed for processing speed. Time began when the load was initially dumped into the hopper and ended after all material completely exited the sifter. Each load contained approximately 0.32 m^3 of material, and the processing times were 64 seconds, 61 seconds, and 60 seconds, yielding an average processing rate of 18.7 m^3/hr.

4.2 Mine Triggering Test

The purpose of the mine triggering test was to assess the potential to trigger antipersonnel mines during the loading, sifting, and exiting material operations using the Orbit Screen Model 68. The loading step is the process of dumping a loaded bucket into the hopper of the sifter (see Figure 13). Next, sifting occurs within the mesh screen, as shown in Figure 14. Then, the sifted materials are conveyed by belt and dumped into a pile to the side of the machine (see Figure 15).

Figure 13: Material Loaded into Sifter's Hopper


Figure 14: Sifting in Mesh Screen


Figure 15: Sifted Material Exiting Conveyor

To achieve triggering statistics, 35 Type 72 antipersonnel MRM mine simulants were placed into 12 loads of the rock/soil mix in groups of 2, 3, or 4. With the sifter powered off, each load was dumped into the hopper and then scanned with the MRM reader to determine the number of mines that were or were not triggered by the loading process (see Figure 16). The machine was then switched on with test personnel carefully watching the mesh screen for MRM mines. As a mine exited the screen and fell onto the belt, the machine was turned off and the reader was used to again scan the mine (see Figures 17 and 18). Last, test personnel observed the sifted material as it exited the conveyor belt. As each MRM was found, it was scanned a third time. Table 6 gives results from each phase of this test.

Figure 16: Scanning MRMs after Initial Dump

Figure 17: Material Exiting Screen onto Conveyor Belt

Figure 18: Scanning MRMs on Conveyor Belt

Table 6: MRM Triggering Test Results

Percentage of mines not triggered in initial dump	**94.3% (33/35)**
Note: Two additional mines were broken up, but not triggered in initial dumping process	
Percentage of mines not triggered during sifting	**100% (33/33)**
Note: One mine was broken up, but not triggered during sifting	
Percentage of mines not triggered when exiting belt	**100% (33/33)**
Note: One mine fell off belt prior to reaching rock pile, but was not triggered	

4.3 Mine Visibility Test

For the mine visibility test, 50 PVC mines were emplaced in loads of the previously described rock/soil mix and processed with the Orbit Screen Model 68 Sifter. As the mines were processed, observers stationed at three locations were asked to note the number of mines visible within each load at various points. These locations (Figure 19) were (A) the point where large material exits the mesh screen onto the exiting belt; (B) perpendicular to the exiting belt, several feet away from the processed pile; and (C) parallel to the exiting belt, several feet away from the processed pile.

Figure 19: Mine Visibility Test, Observers' Locations

In all, 21 loads of rock/soil were processed. The number of PVC simulated mines within each load varied from zero to six. The observer at each position noted the number of mines seen within each separate load (see Table 7). False alarms occurred when an observer reported more mines than were present in a given load. Note that since one mine fell off the exiting belt before reaching the end of the conveyor, observers B and C were exposed to only 49 of the 50 mines.

Table 7: Mine Visibility Test Results

Observer A	
Percentage of mines seen	96% (48/50)
Number of false alarms	0
Observer B	
Percentage of mines Seen	77.6% (38/49)
Number of false alarms	4
Observer C	
Percentage of mines seen	91.8% (45/49)
Number of false alarms	2

Observer A missed two mines but otherwise correctly identified mines during the visibility test. Of the two mines missed, one mine was in a load containing six mines and the other in a load containing four mines. For this reason, it is suspected that in loads with high numbers of mines, there is a greater chance of missing a mine from Observer A's location.

Observer B missed 11 mines and had 4 false detections during the test. Of the missed mines, two mines were missed in a load containing five mines and two were missed in a load containing six mines. These two loads had the most mines. Like Observer A's position, Observer B's position has a greater chance of missing a mine for well-populated loads. The remaining missed mines occurred in the final loads of the test, suggesting that observer fatigue was the probable cause. The four false alarms also occurred in the final loads, which also may be the result of observer fatigue.

Observer C missed four mines and had two false alarms. Like the previous observers, Observer C missed some mines during loads with a large number (i.e., four, five, or six) of mines. In addition, the largest load, which contained six mines, resulted in this observer's two false-alarm calls.

5 Komplet Italia, s.r.l., Rock Crusher Testing

5.1 Crushing Performance Test

The jaw-opening setting on the Komplet Model 48-25 Rock Crusher adjusts the distance between the machine's two crushing plates. For the purposes of this test, the plates were adjusted to separations of 50 mm, 20 mm, and 10 mm. At each setting, at least one full load of rock/soil was dumped into the crusher, and crushing till completion was timed. Table 8 gives the results.

Table 8: Processing Rates, Crushing Performance Results

Setting	Times Recorded	Average Processing Rate
50 mm	110 seconds, 105 seconds	10.7 m^3/hr
20 mm	152 seconds, 193 seconds	6.7 m^3/hr
10 mm	264 seconds	4.4 m^3/hr

After the timed load was processed, a load containing three PVC mock mines was processed at each plate-separation distance. As the separation decreased, the amount of damage to the PVC mock mines and the amount of damage to the rocks within the rock/soil mix increased. Table 9 gives the results from the PVC processing, and Figures 20–22 show some simulants after they went through the crusher at each setting.

Table 9: PVC Mock Mine Processing Results

Setting	Description of PVC Mines after Processing
50 mm	All PVC mines were chewed, but remained whole and intact
20 mm	All PVC mines were chewed and smashed, resulting in a breakup of the plaster that filled the mines
10 mm	All PVC mines were broken into pieces

Figure 20: PVC Mine Simulants, 50 mm Setting

Figure 21: PVC Mine Simulants, 20 mm Setting

Figure 22: PVC Mine Simulants, 10 mm Setting

5.2 Live Mine Triggering Test

A live mine triggering test conducted with the Komplet Rock Crusher was used to determine the likelihood of a mine being detonated instead of being crushed when passing through the rock crusher. A secondary objective was to determine whether the rock crusher could withstand the blast from an antipersonnel mine, should one be detonated during the process. Ten TAB-1 antipersonnel mines were emplaced in various positions inside the hopper, along with some of the rock/soil mix described above. Of the 10 test events, 3 events resulted in high-order detonations with no damage to the rock crusher, 2 events ended in low-order detonations with some of the mine (and its explosive) being crushed to small pieces, and 5 events resulted in crushed mines with no blast. Of the no-blast events, the resulting mine pieces presented some level of hazard given that mine pieces remained (identifiable chunks of explosive). Two of these five events posed additional risk as the mines' fuses, while damaged, were intact. None of the bulk explosive remained in contact with the fuse, however. The crushed mine debris posed some risk, but the overall threat of the mines was significantly reduced by the Komplet Rock Crusher, and no damage to the equipment occurred. An examination of the sifted remains of the crushed mines yielded pieces of the bulk explosive that measured 5–7 mm in size. Figures 23–26 are images from the blast test.

Figure 23: High-Order Blast

Figure 24: Low-Order Blast

Figure 25: Crushed Mine Pieces

Figure 26: Intact Fuse

6 Loader Test

To determine the efficiency of a loader to pick up, transport, and unload rock and soil into the sifter (or the rock crusher), and to determine its effect on antipersonnel mines, a timed loader test was performed. Testing was conducted with a the ASV SR-80 loader equipped with a 0.32 m^3 bucket, as shown in Figure 27, within a 28 m × 11.5 m test area (ranging in depth from 1 to 2 feet) consisting of the rock/soil mix described in section 3.1. Within the inner 185.3 m^2 of the test area, 100 MRM simulants were armed and emplaced, as shown in Figure 28. Because four of the mines simulants were buried outside of the area retrieved by the loader, it was decided that only 96 of the 100 mines buried would be considered for this test.

Figure 27: ASV SR-80 Loader in Operation

Figure 28: Loader Test Area

In total, it took 5 hours to load and sift approximately 90.5 m^3 of the test area, resulting in a processing rate of 18.1 m^3/hr. During this process, all 96 mines were recovered and

55.2% (53/96) of the mines were not triggered. Table 10 is a breakdown of the mine types used and the triggered-mine counts.

Table 10: Loader Test Mine Types and Number Triggered

Mines Buried	
Type 72 antipersonnel	31
PMN	25
PMA-1	19
PMA-2	25
Mines Not Triggered During Loading Test	
Type 72 antipersonnel	30 (96.8%)
PMN	4 (16.0%)
PMA-1	3 (15.8%)
PMA-2	16 (64.0 %)

During operations, the loader tracks passed over a mine once, and a mine fell out of the loader once. In each case, the mine was recovered by the loader.

7 Sifter and Rock Crusher as Single System

After testing was complete, the Orbit Screen Model 68 and Komplet Model 48-25 Rock Crusher were operated together (see Figure 29). As material was processed by the sifter, the large materials that exited by conveyor were sent directly into the hopper of the Rock Crusher for further processing. There were no problems with operating the two machines in tandem.

Figure 29: Sifter, Crusher Joint Operations

8 Transportation

All pieces of equipment used in the demonstration test will have to be transported to and from a work site by flatbed trailer. Work site movement is no problem for the ASV SR-80 loader or for the rock crusher, for reasonable distances. The Orbit Screener Model 68 sifter, however, is not self-propelled and requires a vehicle with a trailer hitch to move it any distance at all. Hooking up and moving the sifter is not difficult, however.

9 Training

The time to train an individual to operate either the orbit screener or the rock crusher was measured in hours. The operating controls on both pieces of equipment are well marked and optimally located to allow watching the equipment as it functions while making control changes. Training with the remote-control box for the rock crusher was also straightforward.

10 Summary of Evaluation Test Results

In the triggering test, a threat represented by antipersonnel mines the size of the Type 72 mine was triggered only twice during the loading, sifting, and discharge process from the orbital sifter. However, during the loading from a minefield test that used stimulants of four different antipersonnel mines, the probability of triggering, depending on the type of mine, could be quite high.

The probability of an observer seeing a mine loaded into the sifter from a point looking down onto the debris discharge belt was quite high: 96% of the mines processed were seen by the observer. Those not seen were missed when a large number of mines were in a single bucket load (more than three per load). This can possibly be attributable to observer overload caused by watching multiple mines, simultaneously, in motion.

The rock crusher crushed, with no detonations, 50% of the live mines processed; caused low-order detonations in 20% of the mines processed; and caused high-order detonations in the remaining 30% of the mines processed. The rock crusher suffered no damage.

The skid-steer loader used during the test showed that it could remove the top 1–2 feet of soil in a minefield environment without any problems. Triggering of the stimulant mines was a function of the type of mine encountered.

10.1 Orbit Screen Model 68A

The orbit screener performed without a single mechanical or operational problem. Should the orbit screener be selected for a field trial, the most important issue to be addressed is where during the screening process, when a mine is detected or sighted, it should be removed from the system. These decisions will depend heavily on the type of mine threat present and the condition of the mines.

Table 11 gives the summary results of the Orbit Screen Model 68A test. Mine-observation test results are those of the primary observer, who watched the debris as it tumbled from the sifting screen onto the discharge belt.

Table 11: Summary, Orbit Screen Tests (MRM Type 72 Mines)

Test Activity	Test Results
Processing rate	18.7 m^3/hr
% of mines seen by primary observer	96% (48/50)
% of mines NOT triggered by:	
• Initial loading (Note that two additional mines were damaged during loading but were not triggered.)	94.3% (33/35)
• During sifting	100% (33/33)
• Dumping onto debris pile	100% (33/33)

10.2 Komplet Model 48-25 Rock Crusher

The Komplet Italia, s.r.l., Model 48-25, performed extremely well, with no mechanical or operational problems. After processing over 61 m^3 of river jack rock, the crushing plates had no discernable wear. In fact, during inspections of the plates after the three high-order blast during the triggering test with live antipersonnel mines, no marks were found.

Table 12 gives summary results of the rock crusher performance tests.

Table 12: Summary Results of Rock Crusher Tests

<table>
<tr><th>Crusher Plate Setting</th><th>Processing Rate</th><th>Damage to PVC Mine Simulants</th></tr>
<tr><td>50 mm</td><td>10.7 m^3/hr</td><td>Deformed but whole</td></tr>
<tr><td>20 mm</td><td>6.7 m^3/hr</td><td>Chewed and smashed</td></tr>
<tr><td>10 mm</td><td>4.4 m^3/hr</td><td>Broken into small pieces</td></tr>
<tr><th colspan="3">Triggering Test on Live TAB-1 Antipersonnel Mines</th></tr>
<tr><th>Crusher Plate Setting</th><th colspan="2">Results (10 Events)</th></tr>
<tr><td>20 mm</td><td colspan="2">3 high-order detonations
2 low-order detonations
5 mines crushed into small pieces, fuse chain separated from main charge</td></tr>
</table>

10.1 Small Loader Test

Table 13 gives the results of the test to determine probability of triggering various types of antipersonnel mines while removing material, including mines, from a minefield and processing the material through an orbital screener. The skid-steer loader used was the ASV SR-80 rubber-tracked vehicle equipped with a Quick Combo 4-in-1 bucket (volume of 0.32 m^3). The loading rate of the vehicle and bucket combination (18.1 m^3) closely matched the processing capacity of the orbit screener (18.7 m^3). Finally, the ASV SR-80 performed throughout the test without a single maintenance or operational incident.

Table 13: Loader Test Mine Types and Number Triggered

Mines Buried	
Type 72 antipersonnel	31
PMN	25
PMA-1	19
PMA-2	25
Mines Not Triggered During Loading Test	
Type 72 antipersonnel	30 (96.8%)
PMN	4 (16.0%)
PMA-1	3 (15.8%)
PMA-2	16 (64.0 %)
Loaded Volume and Time	**Loading Rate**
90.5 m^3 in 5 hours	18.1 m^3/hr

11 Test Findings

Each piece of equipment tested during this performance evaluation test, the Orbit Screen Model 68A, the Komplet Italia, s.r.l., Model 48-25 Rock Crusher, and the ASV SR-80 rubber track loader with the Quick Combo 4-in-1 bucket, met or exceeded the challenge provided by the test protocol and the material. This equipment, used either alone or as part of a system with either one or both of the other machines, would meet the challenge of any minefield clearing operation of equal environmental difficulty and mine threat.